Functional Multi-layer Solution Processable Polymer Solar Cells

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Increasing Morphological Stability

Traces of Solvent Remains in Film after Heat/Vacuum

Gas Chromatography - Mass Spectrometry (GCMS)

(a) Ortho-dichlorobenzene (ODCB) peaks were still detecte after the ODCB-cast films were annealed at 150°C for 1, 5

and 10 minutes in the nitrogen glovebox. b) ODCB peak is still present after 30 minutes in a vacuum

Trace Solvent Caused Agglomerations



eat-treated devices

The size and amount of PCBM agglomera ons increases as the duration of heat treat-

The size of PCBM applomerations in CB-cast amples are smaller compared to ODCB-cast

PCBM Applomerates Reduces Local Photovoltaic Efficiency of Device Laser Beam Induced Current (LBIC) Mapping A 405 nm diode laser is focused to a spot size of 50 µm2 and then scanned over the film using positioning mirrors. The resulting photo

current at each location is recorded. High photocurrents (blue and dark blue regions) detected in regions free of PCBM agglomerates low photocurrents (green) are detected

n regions where PCBM agglomerates are present. Note: size of PCBM agglomerations within the footprint of the calcium electrode appear to be larger than the agglomerations outside

Approach & Results

Optical microscopy shows fewer PCBM agglomerations after 30 minutes of heat treatment at 150°C with addition of 4% of nitronzene (NTB).

hanges in crystallinity of P3HT w.r.t. to temperature can be ex-



that plateaus at approximately120°C for chlorobenzene (CB) cast film, while this transition plateaus at approximately 180 °C for the film with nitrobenzer (NTB) additive. At 50% normalized absorption, the temperature for CBcast film is approximately 87 °C while it is approximately 127 °C for NTB

added film. The 40 °C increase with addition of nitrobenzene indicate that P3HT remains crystalline over a bigger range of emperature. (DSC measurements in progress to study this transition). Preliminary J-V measurements show improved Jsc for devices cast with NTB additive after annealing, i.e. 6.63 mA/cm² for NTB/CB-cast film com pared to 5.34 mA/cm² for CB-cast film.



Fabricating Multilayer Structures

ution processing organic multilayers can be difficult due to the similar solubilities that many of the olymers and compounds have in common organic solvents. Having the ability to construct mul ayer polymer solar cells using solution fabrication techniques would be desirable so that function avers could be included to in

Multilayer Deposition prove device performance. Approach & Results

P3HT/F8BT bilayers hieved by using a set of o nogonal solvents. Here we den strate the ability to control the solubility of a polymer by control-ling the temperature. It was found hat P3HT becomes insoluble in oluene at low temperatures. This allows toluene-soluble polymers to be deposited onto P3HT to create

Manager on

P3HT/PCBM bilayers

prepared by spin coating

ethane onto P3HT films

solvent for P3HT the PI mea-

urements show that there is

substantial amount of ixing of the PCBM into the

nsities it is determined that

the mixing is between 20-30 wt% PCBM. The mixing is

kely due to the swelling of the

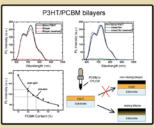
P3HT by the CH,Cl., making it

asier for the PCBM to diffus

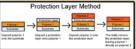
nto the film.

P3HT films. From the PL in

hown above illustrates the bilayer fabrication process. The absorbance and photoluminescent measurments are also shown. Due to the energy transfer between P3HT and F8BT, the 1:1 mis sample shows an almost complete quenching of the F8BT fluorescence. The bilayer shows only artial fluorescence quenching, which demonstrates that there are two distinct layers



Protection Layer Method o the right will allow for multilayer de osition with minimal mixing between ever is a non-solvent that is frozen during multilayer deposition and car



Interfacial Mixing and its Consequences

and mixed polymer/fullerene layers with thicknesses less than 100 nm. The properties of the interfaces dominate the electrical function of the layers. For this reason, an understanding of the interface properties of the polymers used in these devices is needed. Work function measurements predict a blocking interface assuming PEDOT:PSS is a semiconductor. However electrical measure ments show that the interface is Ohmic. It is known that morphol ogy influences the open circuit voltage ($V_{\rm OC}$). Morphology can be adjusted by heating or using non-solvents, such as nitrobenzene



Devices fabricated with P3HT/PCBM active layers cast from pure chlorobenzene (CB) and with NB as an additive indicate the importance of interfaces. V_{OC} is a function of casting solvent, heat treat ment temperature, and HOMO-LUMO gap. However, compensation voltage (V_O) is only a function of heat treatment and is idependent of active layer morphology. This indicates that something other than morphology is controlling V_0 . We show that an interlayer of PSS and P3HT is forming upon heating and is playing an important role in these devices.

Approach & Results

We use contact angle measurements, x-ray absorption near edge structure (XANES), and neutron reflectometry to confirm the pres ence, composition, and thickness of an interlayer. Contact angle neasures the hydrophobicity of a surface. A series PEDOT:PSS/P3HT bilayer samples were fabricated and heated to different temperatures. Some of the samples were washed with CB after heating to remove P3HT. The contact angle of a drop of water

XANES ompared to heated shows that below 150°C all of the P3HT is washed off

Above 150°C the contact angle of the washed samples resembles the unwashed samples indicating the pres-ence of P3HT. XANES measurements performed on many samples confirm the results of the contact angle study. The heated and washed PEDOT:PSS/P3H1 sample has characteristic peaks of PSS and P3HT, in dicating both are present at the surface. The fit to the data indicates a PEDOT:PSS to P3HT ratio of 6:5. Neutron reflectometry measurements also indicate the presence of an interlayer. Values for the

Neutron Reflectometry

scattering length densities of PEDOTPSS and P3HT wer determined by fitting reflectivity data for single layers on sili Scattering length density profiles were used to dete mine if any P3HT is present in an interlayer. The results show P3HT that is a few nanometers thick.

Our measurements confirm the formation of an interlayer a the PEDOT:PSS/P3HT interface upon heating. This inte layer efficiently transports holes from the active layer to the ITL. In the future study interlayer formation with differen polymers. With greater understaning we want to use this in terlay to increase Voc and decrease dark current, thus treasing fill factor.



Contact Angle

Developing New Hole Transport Layer Materials

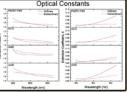
almost all polymer photovoltaic (PPV) devices the hole transport layer (HTL) is the doped conductive polymer poly(3,4-ethylenedioxythic phene): poly(styrenesulfonate) (PEDOT.PSS) because it is conductive ransparent in the visible region, has a stable work function, and, after deposition, is insoluble. The problem with PEDOT:PSS is its acidity pH=1.2). The PSS anion reacts with the indium tin oxide (ITO) anode, iberating oxygen, which oxidizes the polymer, and degrades device perormance. Also, as shown to the left, an interlayer forms between PSS and the active layer polymer decreasing Jon

Approach & Results
To address the issues with PEDOTPSS, a new conductive copolymer has been developed by Plextronics, Inc. known as Plexcore OC®. Three solutions of Plexcore OC® (A110, A120, and A30) are compared to PEDOT:PSS (Clevios P VP Al 4083). The three AJ solutions had diffe

Conductivity ent levels of doping and are less acid (pH=2.1) than PEDOTPSS Measur ments of lateral conductivity show AJ1 PEDOT:PSS 4.4 and AJ30 films have similar conductivities to PEDOT:PSS but AJ20 is not conductive. Interference enhance

variable angle spectroscopic ellipsometry (IEVASE) is used to mod the optical constants. All of the films are found to be uniaxially anise AJ-30 16 tropic and show low extinction in the visible region. PEDOT:PSS
AJ10, and AJ30 had similar optical properties. The ordinary extinction coefficient increases with

ngth, similar to a metal. The ordinary optical constants of AJ20 are different. The ordinary reactive index looks dielectric, which corresponds with its electrical properties. Tapping-mode atomi force microscope (AFM) phase images show PEDOT:PSS, AJ10, and AJ30 have

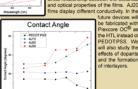


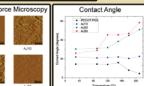
urements show that dopants migrate to the surface upon heating changing the Our results show that AJ10 and AJ30 films have similar properties to PEDOT:PSS films. Conductivity and IEVASE measurements show there is a direct relationship between the electrica

Chemical Structure

PEDOT:PSS

levoore OC®





be fabricated with Plexcore OC® as the HTL instead of will also study the effects of dopants and the formation of interlayers.

